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A REGRESSION MODEL FOR NONDESTRUCTIVE FRUIT VOLUME ESTIMATION IN KARONDA (*CARISSA CARANDUS* L.)

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ABSTRACT

A model relating to karonda (*Carissa carandus*.L.) fruit length and diameter to its volume was derived using the regression analysis. Two year investigation was carried out during 2014 and 2015 under open field conditions to test a whether a model could developed to estimate fruit volume using linear measurements. Regression analysis having FV versus L and D disclosed ten models viz., FV= -4.52 + 0.5(L+D) ^{2,} FV= -18.14 + 5.5(L+D), FV= -48.19 + 37.22$D^{0.5}$, FV= -41.56 + 32.09$L^{0.5}$, FV=2.07+ 0.15L^2D^2, FV= -5.37+ 2.44D^2, FV= -3.44+1.88L^2, FV= -4.55+2.18LD, FV=-19.62+12.02D and FV=-16.08+9.99L that could be used for estimating the volume of individual karonda fruits. Among these models a regression model having LD as the independent variable (FV = -4.55 +2.18 *LD) provided most accurate (R^2=0.98), MSE=0.75) estimate of karonda FV. Validation of the model having LD of fruits from other genotype measured in the 2015 experiment showed that the correlation between calculated and measured area was very high. Therefore, this model can estimate accurately the FV of karonda in many experimental comparisons without the use of any pricey instruments.

INTRODUCTION

The qualitative and quantitative character of fruit is very important in horticultural crops to meet the quality standards, monitoring fruit growth, predicting yield, assessing optimal level of fertilization and irrigation, identification of the cultivars (Demirsoy and Demirsoy, 2007) and also to meet the domestic and International market needs (Wilhelm *et al*., 2005), (Koc , 2007). The size of fruit will determine its market value. Therefore the size of horticultural product is often represented by its weight because it is comparatively easy to measure. However, volume-based sorting and growth monitoring may provide a more efficient method than weight sorting. In addition, the weight of horticultural produce can be estimated from volume if the density of the produce is known (Koc, 2007).

There are many methods to estimate fruit volume in horticultural crops. However, these methods, including water displacement, gas displacement, image processing (Rashidi et *al*., 2009; Koc, 2007; Omid et *al*., 2010; Khojastehnazhand et *al*., 2008), and electronic devices (Jarimopas *et al*., 2005), require the excision of fruits from the plants. It is therefore, not possible make successive measurements of the same fruit. However fruit volume can be measured quickly, accurately and in a non-destructive manner using image analysis with image measurement by using image analysis software. The capture of image by digital camera is rapid, non-destructive and more accurate (Bignami and Rossini 1996), but the processing of images are time consuming, and the facilities required for this method is expensive (Cristofori *et al*., 2007).

Therefore, there is a need to develop simple, inexpensive, rapid, reliable, and non-destructive method for measuring fruit volume in different fruit crops by the horticulturists. The mathematical relationships between fruit volume and dimensions of the fruit (length and diameter) could be clarified, a method using just linear measurements to estimate fruit volume would be more advantageous than many of the methods are mentioned above (Villegas *et al*., 1981; Beerling and Fry, 1990). Various combinations of measurements and various models relating length and diameter to volume have been developed for several fruit and vegetable crops, such as apples (Batjer *et al*., 1957), muskmelon (Currence *et al*., 1944; Jenni *et al*., 1997), pear (Mitchell, 1986; Williams *et al*., 1969; Ortega *et al*., 1998), bell pepper (Ngouajio *et al*., 2003), apricot (Arzani *et al*., 1999), peach (Demirsoy and Demirsoy, 2007), while the information on fruit volume estimation in karonda (*Carissa carandas* L.) is still lacking.

Karonda (*Carissa carandas* L.) is a species of flowering shrub belongs to family Apocynaceae and order Gentianales. Flowers were white, scented and important source of nectar for different butterfly species (Atluri *et al*., 2011). It produces berry-sized fruits and these are commonly used as a condiment in Indian pickles and spices. It is a hardy, drought-tolerant plant that flourishes well in a wide range of soils, in regions with high temperatures and thrives well throughout tropical and sub tropical climate. In India, it grows wild in states of UP, Bihar, West Bengal, lower, outer and middle Himalayas, Rajasthan, Uttarakhand, Maharashtra and parts of southern India (Malik *et al*., 2010). Therefore, the this study deals with development of different linear regression models for fruit volume prediction and evaluation of the developed linear regression models.

MATERIALS AND METHODS

The present study was performed in a karonda orchard located at Central Horticultural Experiment Station (CHES), Chettalli, Kodagu, Karnataka, India (latitude 12°59'N, longitude 75°84'E, altitude 609m) in a very deep, well drained clay soils with iron gravel horizon. The annual mean temperature was 21.6°C, with annual rainfall of 1450 mm. Ten karonda accessions (Konkan bold (layered) Vengurla (open pollinated), Konkan bold (open pollinated), Konkan Big, Vengurla Big, Thakurwadi local, Vengurla small, Konkan small (open pollinated), Vengurla big (open pollinated) and Thakurwadi (open pollinated) were used to develop a fruit volume prediction models. These accessions were planted in the year 2006 and maintaining at spacing of 6 x 6m. Fruit sampling was performed in early June when the fruits were fully developed. Fruits were selected randomly from different levels of the shrub canopy ranging from 1 to 3m from the soil level and all around the crown. Thirty fruits were sampled from each accession. Total of 300 karonda fruits (30 fruits per accession) were measured for fruit volume (FV), fruit Length (FL) and fruit diameter (FD) in the preliminary calibration experiment coming from ten accessions.

The weight of fruits was measured with weighing balance (Sartorius, CP324S). The volume of fruit was measured using water displacement method. The dependent variable FV were regressed with different independent variables, including L, D, $L^{0.5}$, $D^{0.5}$, L^2, D^2, L^2D^2, $(L+D)^2$ and product LD in combination of all genotypes.

Mean square error (MSE) and the values of the coefficients (a) and constants (b) were also reported, and the final model was selected based on the combination of the highest coefficient of determination (R^2) and the lowest MSE.

Moreover, using two measurements (*i.e.*, length and diameter) introduced potential problems of co-linearity, resulting in poor precision in the estimates of the corresponding regression coefficients. For detecting the variance inflation factor (VIF) (Marquaridt., 1970) and the tolerance values(T), were also calculated (Gill., 1986).

$$VIF = \frac{1}{(1 - r^2)}$$

$$T = \frac{1}{VIF}$$

Where *r* is the correlation coefficient between length and diameter of fruit. If the VIF value was higher than 10 or if *T* value was smaller than 0.10 then co-linearity may have more than a trival impact on the prediction of the parameters, and consequently one of those should be excluded from the model (Gill., 1986). In order to validate the developed model and to increase practical applicability, a validation experiment was conducted in the summer 2015 on fruit samples of other genotype (Thakuwadi OP) grown at experimental farm of CHES, Chettalli. Total 30 fruits of the local genotype were used to determine fruit length, fruit diameter as well as fruit volume using the best predicted model from the calibration experiment and was compared with actual fruit volume. Moreover, to compare the predicted fruit volume (PFV) and the observed fruit volume (OFV), the season of local genotype growing and graphical procedures (Martin Bland and Altman, 1986) were used. Scatter plots of values for the PFV against the OFV are presented in (Fig. 2). SPSS 16.0 programme was used to evaluate the linear relationship for OFV and PFV of the local genotype.

RESULTS AND DISCUSSION

The models derived through linear regression procedure were simple to use. These models use both fruit diameter and fruit length as input variables. Regression analysis demonstrated a strong relationship ($P < 0.001$) between fruit volume (FV) and fruit length (FL), fruit diameter (FD), the product of length and diameter (LD), the square of the sum of length and diameter $(L+D)^2$, the square of length (L^2) and the square of diameter (D^2) among the selected genotypes (Table 1.).

As a preliminary step to model calibration, the degree of colinearity among L and D was analyzed. The VIF was ranged from 4.3 to 6.0 and T values ranged from 0.12 to 0.19, depending on genotypes respectively. In, all selected

Table 1: Fitted coefficient (b) and constant (a) values of the models used to estimate the karonda fruit volume (FV) of single fruits from length (L) and diameter (D) measurements.

Model Number	Form of model tested	Fitted coefficient and constant[a] aa	b	R^2b	MSE[b]	RMSE
1	$FV = a + b(L+D)^2$	-4.52 (0.33)	0.54 (0.01)	0.98	0.77	0.88
2	$FV = a + b(L+D)$	-18.14 (0.81)	5.55 (0.17)	0.96	1.21	1.098
3	$FV = a + bD^{0.5}$	-48.19 (2.24)	37.22 (1.48)	0.94	1.98	1.41
4	$FV = a + b(L^{0.5})$	-41.56 (2.07)	32.09 (1.33)	0.93	2.14	1.46
5	$FV = a + b(L^2 D^2)$	2.07 (0.21)	0.15 (0.004)	0.97	0.86	0.93
6	$FV = a + b(D^2)$	-5.37 (0.41)	2.44 (0.07)	0.97	1.01	1.01
7	$FV = a + b(L^2)$	-3.44 (0.44)	1.88 (0.07)	0.95	1.52	1.23
8	$FV = a + b(LD)$	-4.55 (0.33)	2.18 (0.05)	0.98	0.75	0.87
9	$FV = a + b(D)$	-19.62 (0.99)	12.02 (0.42)	0.95	1.56	1.25
10	$FV = a + b(L)$	-16.08 (0.95)	9.99 (0.38)	0.94	1.84	1.36

[a] standard errors in parenthesis; L and D were in cm; [b] Coefficient of determination (R^2), mean square errors(MSE in cm^2) of the various models are also given. All data were derived from the calibration experiment held by 2014(n = 300fruits)

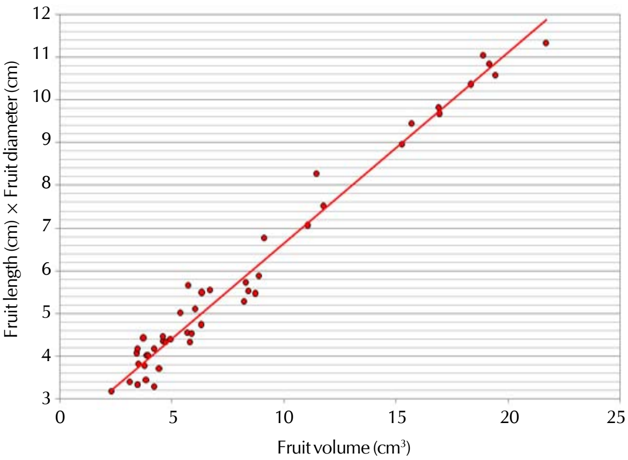

Figure 1: Relation between fruit volume (FV) and fruit length (L) x Fruit diameter (D) of fruits from ten genotypes measured in the calibration experiment (2014). The regression equation is FV = -4.552+2.181*LD

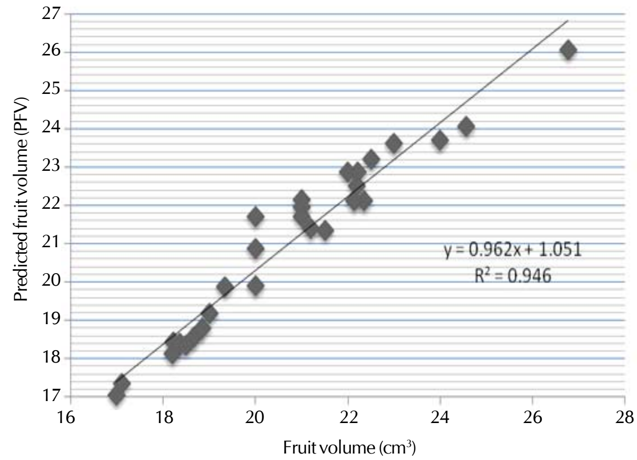

Figure 2: Observed vs. predicted values of fruit volumes of karonda during 2015 (validation experiment) using model number 8 FV = -4.552+2.181*LD. Where FV is individual fruit volume (cm³) and LD is the product of fruit length (cm) X fruit diameter (cm). Solid line represents linear regression lines of Model 8. Dotted lines represent the 1:1 relationship between the measured and calculated values

genotypes, VIF was < 10 and T was > 0.10, showing that the co-linearity between fruit length and diameter can be considered negligible. Therefore both the variables were included in the model (Gill., 1986) to avoid the experimental errors.Similar studies were conducted on some species of fruit trees such as peach (Demirsoy and Demirsoy, 2007), apricot (Arzahi *et al*., 1999), pear (Ortega *et al*., 1998), where the fruit size estimation models were developed using the linear measurement of fruits.

Among, all the models developed, the model number 8 (FV = -4.552+2.181*LD) was selected for its highest R^2 (0.98), smallest MSE (0.75) (Fig. 1). Although model number 1 FV = $-4.52+0.543*(L+D)^2$ had same R^2 (0.98) as model number 8, the preference was give to model number 8, because of its easy calculation and lowest MSE. Except for Model 3, 4 and 10, all models produced a coefficient of determination (R^2) equal to or greater than 0.95 (Table 1).

Comparisons between measured versus calculated fruit volume using model number 8 FV = -4.552+2.181*LD for the validation set derived from 2015 experiment, showed a high degree of correlation and provided quantitative evidence of the validity of volume estimation model (Fig. 2). The results indicated that a high correlation (R^2= 0.946, P<0.0001), between OFV and PFV. Finally, it may be concluded that length-diameter model can provide more precise estimation of karonda fruit volume than those based on single length or diameter measurements. Measuring fruit length and diameter are easy access parameters in the field. Therefore, use of this model would enable researchers to make non-destructive or repeated measurements on the same fruits. This model may be accurately utilized to estimate the fruit volume in karonda shrubs without use of common method of volume measurements like water displacement, gas displacement and expensive instruments, e.g., image processing software or machine vision techniques. To summarize that, it was concluded that the fruit length-diameter model (i.e. Model 8) can provide precise estimation of karonda fruit volume across genotypes and environments. With this model, horticulturists, agronomists and physiologists can estimate fruit volume of karonda accurately.

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